



# tech briefs

Westinghouse Savannah River Company

## New process recycles used tires

### BioWave™ Treated Rubber

#### at a glance

Enables higher percent use of crumb rubber in recycled rubber products

Enables use of larger crumb rubber particles

Lowers viscosity during processing, which improves process economics

Produces improved recycled rubber composites

U.S. Patent 6,407,144

#### for more information

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BioWave™ is a trademark  
of Westinghouse Savannah River Company

Scientists at Westinghouse Savannah River Company (WSRC) have developed a new process to recycle used tires while maintaining useful mechanical and physical properties inherent in the tire rubber. The BioWave process treats conventional crumb rubber with a two-stage method combining microbial oxidation and microwave energy. The resulting treated crumb rubber has the potential of being mixed with new tire rubber to create tires, and with virgin rubber to create other rubber products, containing 20 percent or more recycled rubber.

#### Breaking the sulfur cross links

A variety of additives, including chemical accelerators, promoters, and initiators, are used during the vulcanization process when tires are made. Many sulfur cross links are inherent in the resulting vulcanized tire rubber. The retention of these cross links in used tire crumb rubber makes it difficult to produce a composite of untreated crumb rubber and new tire rubber without significantly degrading important properties of the end product. Previous attempts within the industry to produce a recycled tire while maintaining acceptable mechanical properties have resulted in a tire containing only five percent crumb rubber.

With the BioWave process, microorganisms use sulfur constituents on the surface of crumb rubber as metabolic and/or energy sources, thereby oxidizing the surface carbon-sulfur (C-S) and sulfur-sulfur (S-S) bonds, or cross links. In a second stage of the process, the crumb rubber is exposed to microwave radiation and radiant heat, causing alteration of additional surface as well as interior C-S and S-S bonds. This combination of surface and bulk treatments increases the number of free radicals available for bonding with new tire rubber or virgin rubber while leaving the polymer backbone of carbon-carbon (C-C) bonds almost unbroken. The resulting treated crumb rubber exhibits a tackiness indicative of its readiness for mixing with new tire rubber or with virgin rubber.

#### Testing tire tread

The BioWave process has been successfully tested on 40 mesh truck tread crumb rubber. The treated rubber was incorporated into a literature formula (Bierkes) tire tread composition using a Banbury mixer. The tread compound comprised 20 percent treated crumb rubber and 80 percent new tire rubber. The tread compound was compared with a compound containing 20 percent untreated crumb rubber and with a compound comprising 100 percent new tire rubber. Testing and measurement of various compound parameters were done in accordance with ASTM standards. The results are shown in the table on the back.

Plasticity, tensile strength, elongation at break, and energy at break are among the most important measured parameters for tire compositions. It is significant to note that the tread compound containing 20 percent of the BioWave treated crumb rubber outperformed the compound containing 20 percent untreated crumb rubber in all four categories. The BioWave treated crumb rubber compound exhibited 16.4 percent lower plasticity, 9.5 percent greater tensile strength, 20.8 percent better elongation at break, and 34.7 percent better energy at break. Of particular

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#### Performance Parameters

	New Tire Rubber	20% Untreated Crumb Rubber	20% BioWave Treated Crumb Rubber
<b>Uncured Properties</b>			
Plasticity [Mooney units]	60.5	87.3	73
Scorch (t5) [minutes]	24.58	20.26	20.22
Scorch (t35) [minutes]	28.62	24.47	23.35
Min. Viscosity [Mooney units]	41.24	62.67	50.10
<b>Cured Properties</b>			
Shore Hardness	67.7	66.1	64.5
Modulus at 100% [MPa]	2.43	2.02	1.79
Modulus at 300% [MPa]	3.44	2.66	2.13
Tensile Strength	21.51	16.38	17.93
Elongation of break (%)	421	414	500
Energy @ break [Joules]	16.64	12.54	16.89
G' (10%) [MPa]	2.679	2.935	2.582
Tan delta	0.288	0.275	0.322
<b>Analytical Characterization</b>			
Acetone Extract [% by weight]	10.34	10.26	10.52
Oxygen [% by weight]	1.63	1.42	1.68
Zinc Oxide [% by weight]	2.79	2.55	2.68
Macro Ash [% by weight]	3.01	3.44	3.80

## BioWave™ Treated Rubber

note, the compound containing 20 percent of the BioWave treated crumb rubber actually outperformed the compound comprising 100 percent new tire rubber in two of the four categories, elongation at break, and energy at break.

The BioWave process has been developed only to the point of proving concept feasibility and usefulness and has not yet been optimized. Hence, it is reasonable to expect that additional development to maximize the process will yield further improvements. Also, the favorable results achieved at the 20 percent loading level suggest that much higher loading levels may be achievable in a cured end product suitable for use in a range of high quality rubber products.

#### Benefits

In addition to the obvious environmental benefit of enabling the recycling of used tires, the BioWave process promises to be economical. The process produces a homogenous feedstock with reduced viscosity during processing, which requires lower processing temperatures. Also, being able to use higher loading levels of recycled rubber and larger crumb rubber particles reduces the cost of raw materials as well as the amount of virgin rubber needed.

#### Applications

The BioWave process should yield a product that can be incorporated in compositions used in tire applications including tire treads, sidewalls, beads, carcass plies, belts, and possibly bladders. Use of the product in compositions for other molded rubber end products will be determined by required end product characteristics and by economics.

#### Partnering opportunity

United States Patent 6,407,144 has been issued on this invention. The invention has been developed and demonstrated to the point of proving concept feasibility and usefulness.

WSRC invites interested companies with proven capabilities in this area of expertise to develop commercial applications for this process under a cooperative research and development agreement or a licensing agreement. Interested companies will be requested to submit a business plan setting forth company qualifications, strategies, activities and milestones for commercializing this invention. Qualifications should include past experience at scaling up similar processes, reasonable schedule for commercial process launch, sufficient processing capacity, established sales avenues, and evidence of sufficient financial resources for process development and launch.

#### Technology transfer

WSRC is the managing contractor of the Savannah River Site for the United States Department of Energy. WSRC scientists and researchers develop technologies designed to improve environmental quality, support international nonproliferation, dispose of legacy wastes, and provide clean energy sources.

WSRC is responsible for transferring technologies to the private sector so that these technologies may have the collateral benefit of enhancing U.S. economic competitiveness.